



*X.—Illustrations of the Fauna of the St. John Group.**By G. F. MATTHEW, M.A.*

(Read May 25th, 1882.)

## NO. 1.—THE PARADOXIDES.

*Their History.*

Two decades have now elapsed since the discovery of trilobites in the slates near the city of St. John, New Brunswick, Canada. The preliminary notice of these fossils by the late Professor C. F. Hartt appeared in the report of the geological survey of New Brunswick (1865) carried on under Prof. L. W. Bailey, and descriptions of the species appeared a little later in Principal Dawson's "Acadian Geology" (1868). Since that time the structure of the region in which these fossils were found has been worked out by officers of the Geological Survey of Canada, so that the conditions under which the primordial fauna existed in Acadia are now better known than when the first explorations were made. The knowledge of the geological structure of the region, thus acquired, is embodied in various reports of the Geological Survey, and especially in those of 1870-1 and 1878-9, and the map which accompanies the latter report.

From these reports and from the map it will be seen that the strata of the St. John group fill a number of narrow, trough-like basins, lying between the Bay of Fundy and the central Carboniferous area of New Brunswick. Of these basins, that on which the city of St. John is situated is the most important, and it is here also that the life of the period can be studied to the best advantage. The St. John basin lies diagonally across the ridges of Huronian rock that are found in the eastern part of St. John county; and touches the ridge of Laurentian rocks that divides this county from King's. As might naturally be expected the coarser sediments found at the base of the St. John group are largely derived from those older rocks, chiefly the Huronian; and the line of division between it (the St. John group) and the Huronian Formation is marked by conglomerates of mechanical origin which shew no trace of the hardening process by which the Huronian conglomerates and breccias have been so firmly cemented.

The conglomerates of the St. John group are most fully developed in the eastern part of the St. John basin, under the lee of the high ranges of Huronian hills which exist in that direction. In Portland and the city of St. John, at the western end of the basin the following section represents the succession of members in this group in ascending order:—

Division 0.	a Red conglomerate—wanting at that part of the basin where this section was made.....		Thickness in feet.
	b Red and green sandy slates.....	150	
" 1.	a Coarse grey sandstone or quartzite.....	50	
	b Coarse grey sandy slate (Linguloid shells).....	50	
	c Fine grey and dark grey slaty shales (Trilobites, etc).....	25	
	d Fine black carbonaceous slaty shales ".....	75	
" 2.	a Dark grey slates with thin seams of grey sandstone.....	220	
	b Coarse grey slates and grey flagstones.....	200	
	c Grey sandstones and coarse slates (Linguloid shells).....	130	
" 3.	a Dark grey, finely laminated slates.....	450	
	b Black carbonaceous and dark grey slates, less fissile than the last.	300	
" 4.	Slates and flags resembling 2 a and 2 b (Linguloid shells).....	800	
" 5.	Black carbonaceous slate like 3 b (Orthis, Trilobites, etc).....	450	
		2900	

Beyond Division 5 the beds are supposed to be repeated by an overturn, and have a width across nearly vertical measures of 3000 feet. Owing to this folding of the measures there is some uncertainty as to where the summit of the formation is, and the section given may not include the whole series of deposits. The faunæ of Divisions 2 and 5 are very imperfectly known, but there are much larger species of linguloid shells in these divisions than in Division 1; and the orthids of Division 5 are different from *Orthis Billingsi* of Division 1.

The conglomerate at the base of the St. John group marks the time when the sea of the Acadian epoch invaded the valleys of the Huronian formation near St. John. No trace of life has yet been found in these coarse sediments, nor in the red and green slates into which they pass. After the coloured mud of which these slates are composed was deposited an abrupt change took place in the character of the deposit, and white sands were evenly spread over the whole basin. It is in the upper part of these sands that one meets with the earliest traces of primordial life. These first forms are linguloid shells of several genera. Such shells become more abundant in the upper part of the white and grey sandy beds, and were evidently littoral species, as on tracing the sandstones westward for half a mile they are found to change into a grey slaty and pebbly deposit,—evidently an old beach line—and finally disappear.

Probably the physical condition of the St. John basin at this early period was unfavorable to the growth of the trilobites; but the land was sinking and an additional depth of water in this sheltered area soon encouraged the growth and multiplication of the crustacean fauna. As the sediment which settled from the sea-water in this deepening bay became finer, the remains of marine animals were preserved in greater numbers and variety, so that in the layers of fine slate in group c. of Division 1, many genera characteristic of the early Cambrian age are found.

In group d, the slaty mass becomes quite fine and dark colored, but near St. John,

is much affected by slaty cleavage, and the fossils are so much distorted, especially in the upper part, as to be unrecognizable.

In the beds of Division 2, a return of littoral conditions, and the influx of sand, interfered with the prosperity of the crustacean fauna, and as in the lower sand beds of Division 1, linguloid shells become the prevailing fossils. The *Paradoxides* which I will describe in this article, are those of the intermediate mud-beds, now converted into a mass of slaty rock (Division 1c).

Trilobites were first found in this formation by Rev. C. R. Matthew, in 1862, at Coldbrook, five miles N. E. of St. John, but these specimens were so much distorted by slaty cleavage as to be barely recognizable as trilobites. Specimens, however, were subsequently found near St. John, in the same band of slates, but in a much better state of preservation. Owing to a misapprehension on the part of the late Professor F. C. Hartt as to the locality from which these fossils came, the species when described by him were accredited to Coldbrook, whereas they were really found within the limit of the town of Portland, just northward of St. John.

These collections, with those of the Geological Survey of New Brunswick (1864), supplemented by a collection made by Prof. Hartt's father, J. W. Hartt, in the following year, formed the material from which Prof. Hartt described the species peculiar to this formation. A preliminary notice of these fossils was published in Dr. L. W. Bailey's report on the geological survey of New Brunswick (Fredericton, 1865), and it was shown that they were equivalent to the primordial fauna of Bohemia; but the full descriptions of the species did not appear at that time. These were given subsequently in the new edition (1868) of the *Acadian Geology*, by Dr. J. W. Dawson. The forms described by Prof. Hartt were *Conocephalites* (*Conocoryphe*), 14 species; *Agnostus*, 2 species; *Microdiscus*, 1 species; *Paradoxides*, 1 species; *Lingula*, 1 species; *Obolella*, 1 species; *Orthis*, 1 species; *Discina*, 1 species; and (by the late Mr. E. Billings) *Eocystites*, 1 species. Prof. Hartt's engagements in the United States and his explorations in Brazil, whither he finally transferred himself after his appointment as director of the Geological Survey of that country, prevented him from giving any further attention to the geology of this region; and from the time of the publication of his species in the *Acadian Geology*, but little has been added to our knowledge of the fauna of the St. John group.

Collections made from time to time during the progress of the Canadian geological survey in New Brunswick, were examined by the late Mr. Billings, palæontologist to the survey, and among these were found fragments of *Elliptocephalus* and *Salterella*, and remains of two species of *Hyalolithes*. Beside these, there are the supposed plant remains *Palæophycus*, *Eophyton*, etc., of the higher divisions of the St. John group, to which I need not refer further in this connection.

In the spring of 1877, I made large collections of material from this formation with the intention of studying its fauna, but these were destroyed in the disastrous fire which swept over the city of St. John in the summer of that year. I have since renewed these collections in part, and the following article describes the remains of *Paradoxides* found in the materials collected in these later years.

*Conditions under which the fossils are found.*

One great obstacle to the study of the organic remains of these ancient rocks is the

universal prevalence of slaty cleavage. This in most cases has distorted and obscured the fossils of the finer beds of the formation and, indeed, obliterated them entirely in the greater part of the fine slates. It is only lately that I have been able fairly to appreciate the wholesale destruction of organic forms affected through this agency.

During the extensive excavations that were made for the foundations of buildings in the principal streets of St. John, during the two years after the great fire of 1877, large quantities of fine black slate were removed, in which no trace of a fossil could be seen. But scattered at intervals through some of the bands of this slate there were hard compact masses of rock which, when broken, were found to be packed with fossils. The spherical and elliptical masses, which varied in size from about a yard in diameter to nodules of one inch across, had the appearance of imbedded boulders, but the fossils in them were always parallel to the stratification, and similar fossils were subsequently found in irregular beds and lenticular bands of hard rock. In the boulder-like masses there were numerous layers loaded with organic remains, which extended without diminution in the number of the fossils to the very edge of the block, where they suddenly disappeared, and not a trace of them could be found in the adjoining slate rock. The explanation of this curious fact seems to be that in the hard lump there was sufficient carbonate of lime to resist the molecular movement which produced slaty cleavage in the surrounding portion of the deposit, and thus to preserve the fossils from destruction.

There are three great bands of black slates in the mass of the Saint John group on which the city is built, but which, owing to their softness, seldom appear at the surface, and it is highly probable that these bands originally abounded in organic remains. Such having been the destructive action of slaty cleavage on the Cambrian organisms of this district, the rarity in the finer sediments of fossils in a good state of preservation can be better understood. It is necessary to seek over large areas for such, and as a rule they have been found only near the base of the formation.

Of all the genera of trilobites of the Saint John group *Paradoxides* appears to be that which has suffered most from the distortion due to the movement which produced slaty cleavage in the clay slates. Their tests were more flexible than those of the other genera, and their comparatively large size makes it more difficult to obtain specimens which will show the whole buckler (or even a considerable part of it) in a good state of preservation. The remains of this genus usually resemble crumpled fragments of grey or brown paper, laid irregularly one over the other, without any recognizable shape. When they are not too much crumpled and have their broadest surface parallel to the cleavage planes of the clay-slate they can generally be identified; but the fossils are almost always at an angle with the cleavage, and are also more or less distorted diagonally to the axial line. Even when in the best state of preservation in the argillaceous matrix they are flattened by pressure and the tests cracked and mis-shapen. All these accidents of preservation, except the vertical flattening, have been allowed for in the drawings accompanying this article. In a few cases specimens have been obtained which have been preserved from distortion by a large amount of carbonate of lime in the particular part of the layer in which they occurred, and in these original form of the organism has been more accurately preserved.

The principal fossiliferous zone of the St. John group contains the exuviae of many generations of trilobites, and probably those of several stages of growth of the same individual. Being a repository of the discarded clothing of many a living trilobite, as well as



the cemetery of countless myriads of adult forms, it is not surprising that the wealth of fragmentary tests is bewildering; and when to this is added the variety of appearance given to the test of each species by the forces which produced cleavage in the slates, the profusion of shapes is exceedingly perplexing, and embarrasses the observer in his attempt to reduce this chaos to order.

Owing to the looseness with which they are organized, as compared to the other trilobites, and the number of fragments required to complete the skeleton, the *Paradoxides* are not the least puzzling. In only three instances has the writer met with a complete trilobite, and none of these are of the genus now under consideration. Therefore the description of the species will be confined to the part of the test enclosed within the facial sutures.

*Inter-relationship of the forms.*

One feature in the aspect of the Acadian species of *Paradoxides*, thus far discovered, which immediately arrests the attention is the invariable presence of long eyelobes, set far back on the head. In all the species these lobes extend at least as far back as the occipital furrow, and generally to the occipital ring, and in a few cases seem to be on a line with the back of the ring. In this respect the St. John *Paradoxides* have a *facies* differing from any others on this continent with which the writer is acquainted.

In the Braintree, (Mass.) species (*P. Harlani*, Green) as represented in Dana's Manual of Geology, the eyelobe is short, not extending as far back as the first glabellar furrow; and in the Newfoundland species, described by the late Mr E. Billings, the base of the eyelobes is on a line with the first glabellar furrow. Through the kindness of Mons. J. Barrande, however, the writer has been directed to the figures and descriptions of Bohemian trilobites from which it appears that forms with continuous eyelobes are not unknown in Europe. In his Silurian System Barrande figures a species, *P. rugulosus*, Corda, which closely resembles one of those I am about to describe, but differs in the shorter posterior margin and in the form of the pygidium from any of the species found at St. John. Mons. Barrande has also kindly sent to the writer a sketch of a Scandinavian species, of larger size, which possesses a continuous eyelobe. This form differs from ours not only in the shape of the eyelobe and in other respects, but the peculiar pygidium is very unlike any that are found at St. John. Dr. Henry Hicks, to whom I have submitted tracings of our species, does not recognize any as known to him in the English Cambrian rocks, and I am therefore led to suppose that all the St. John species are new.

Though having in common this peculiarity of a continuous eyelobe, there is much diversity of form in other respects. The glabella varies in outline and height, and in the direction and deepness of the furrows, the anterior margin in length and flexure, the eyelobe in curve and elevation, the posterior margin in width and direction. Some of these differences may be due to age, or to distortion and pressure, but mere variation from mechanical causes will not account for all the forms of the glabella, &c., observed in the St. John *Paradoxides*. When, also, the surface markings of the tests and the variety of hypostomes, pygidia and moveable cheeks is considered, it is clear that the St. John beds contain a number of species of this genus of trilobites. With the imperfect material at command, however, the writer is not prepared to describe more than two species, besides that already described by the late Prof. C. F. Hartt, as *P. lamellatus*. Among the glabellæ,

&c., observed, there are probably other species and possibly some of the forms which the writer has included as sub-species, or varieties of the species first described in the following pages, will hereafter, when the parts are better known, be found to be well defined species.

*Description of the Species.*

The preceding remarks will serve as a general guide to the relationship of the species; and is introductory to the following more detailed descriptions. At the risk of including some features that may be accidental, full descriptions of the form and aspect of the several parts of the head in the species examined, have been given. The descriptions have been arranged in a fixed order for convenience in comparing the parts of one species with those of another.

In these pages I have described only the parts of the cephalic shield, between the facial sutures, reserving for another occasion a description of the movable cheeks, pygidia, hypostomes, and other parts, of which at present the majority cannot with certainty be referred to the species hereafter described.

PARADOXIDES ETEMINICUS. (Figs. 7-12)

The anterior margin is arched around the front of the glabella and thence to the extremity is straight. The summit of the fold is flat and divided from the glabella and the flat area of the margin by an abruptly descending slope; the marginal fold is twice as wide at its extremity as it is in front of the glabella. The flat area is about twice as long in front as at the suture. The sinus at the suture is broad and open.

The glabella is about one-sixth longer than wide; it is narrowed toward the base, but in front expands and rises into a rounded dome, upon which the third and fourth furrows are sometimes only faintly impressed.

Glabellar furrows.—The first two are strongly impressed and cross the glabella: the first furrow is arched backward in the middle and is most deeply impressed in the outer third, especially at the extremity. The second furrow as a whole is parallel to the transverse axis of the shield; its outer third is convex forward, is deeply and sharply impressed and is arched backward to an impressed point on the glabella; the middle third is more broadly marked and is convex backward; the convexity of the outer third is directed forward. The third and fourth furrows are faint and are in pairs; the third furrow is moderately arched with the convexity forward; it extends nearly one-third across the glabella, and is directed forward at an angle of about twenty degrees. The fourth furrow is parallel to the third, and extends about one-quarter across; in the adult it is about half way from the front of the dome.\* Neither of these two furrows reach the outer margin of the glabella.

The occipital ring is roughly rectangular in outline; it is high behind and slopes gradually to the occipital furrow; the posterior edge is straight for half its length, and inclines sharply forward; at the extremities it is moderately arched vertically. The occipital furrow

\* I have used this term as a convenient one to designate the larger anterior part of the glabella of *Paradoxides* included between its front and the second furrow.

is deeply impressed in the outer quarter of its length; the middle half is more lightly impressed, and is convex forward.

The posterior margin is arched vertically in the middle, and also arched backward in the outer half. The marginal fold is narrow, is flattened and widens a little in the outer half, and slopes gradually to the posterior furrow. The furrow is about three times as wide as the fold, is broadly rounded in the bottom, and depressed at both ends, especially the outer.

The fixed cheek is broad, particularly in the posterior third, and a slight depression runs lengthwise across it; the posterior end is elevated next the glabella and the bounding furrows of the cheek are shallow, but distinctly defined. The ocular lobe has a full parabolic curve of which the chord is more than twice as long as the height of the curve; the posterior end is elevated into a tubercle-like lobe which overhangs the posterior marginal furrow.

*Sculpture.*—The anterior marginal fold is traversed by very fine parallel raised lines, which at intervals anastomose, or die out on the surface of the test. There is a good deal of variation in the number and fineness of these lines, which are more widely set on the inner two-thirds than on the outer edge of the marginal fold; there are from eight to twelve of these lines toward the outer end of the fold; in some cases there are about four widely set lines on the inner three-fifths, and about six closely set lines on the outer two-fifths of the marginal fold. The front half of the dome of the glabella is ornamented with irregularly parallel, occasionally forking, concentric, raised lines, similar to those of the anterior marginal fold, but more distinct; these lines are most widely set on the front slope of the dome where there are about 4 or 4½ in the space of one millimetre. There is a band of small tubercles extending along the axial line of the shield from the posterior edge of the occipital ring to the dome of the glabella; these tubercles are most distinct on the occipital ring and can scarcely be resolved by the eye along the rest of the band, but are clearly discerned with a moderate magnifier. A similar band of smaller tubercles extends along the posterior furrow and passes thence into the inter-ocular furrow, along which it extends as far as the anterior end of the ocular lobe. The rest of the shield is covered with minute granulations, visible with a lens of one inch focus, which blend with the bands of tubercles above described.

*Dimensions.*—The largest shield observed was about an inch and quarter long and an inch and a half wide.

*Locality.*—This species is of frequent occurrence in the slates of Division 1c. in Portland, and has also been found at Radcliffe's stream, Simonds, St. John county.

*Name.*—Derived from that of a tribe of Acadian aborigines—the Etchemins.

#### *Growth and Development of the Young.*

Five or six stages in the growth of this species were observed, in which a very considerable change takes place from the young to the adult form. In order to make these changes during growth more clearly appreciable, the writer has appended a table of measurement of several heads obtained near St. John, and has noted in the margin the amount and direction of the distortion of the test, to explain some anomalous measurements which appear in the table. The following marks are used: "o," indicates that the natural form has been preserved; "+," indicates that the specimen has been flattened, but not distorted laterally; "—" indicates that the specimen has been contracted transverse to the direction



of the dash; "→" indicates the direction (towards the head of the dagger) in which the test has been pushed by pressure. The specimen is supposed to be viewed with the anterior end upward. The figures in the columns of the table are proportional measurements, based on the length of the shield.

MEASUREMENTS OF CEPHALIC SHIELDS.

Stages of Growth.	Suture.				Axial Line.					Transverse Diameter.						Distortion.
	Posterior Margin.	Cord of Ocular lobe.	Anterior Margin.	Sine of Eye-lobe.	Occipital Ring.	Glabella.			Anterior Margin.	Basal.		Middle.		Anterior.		
						First Lobe.	Second Lobe.	Dome.		Posterior Margin.	Occipital Ring.	Fixed Cheek.	Glabella.	Anterior Margin.	Glabella.	
4.5 millimetres.	.07	.50	.21	.18	.14	.07	.14	.43	.18	.24	.29	.36	.29	.29	.43	+
10.2 "	.08	.44	.28	.17	.16	.09	.13	.50	.09	.28	.38	.44	.44	.25	.53	+   slight.
21.8 "	.12	.47	.24	.19	.16	.07	.13	.59	.06	.30	.41	.41	.44	.32	.65	+   slight.
22.4 "	.09	.46	.23	.19	.14	.09	.13	.57	.06	.27	.40	.37	.43	.26	.60	
24.4 "	.11	.41	.28	.17	.17	.08	.11	.53	.07	.27	.37	.37	.38	.26	.51	+
26.2 "	.07	.46	.24	.21	.16	.08	.12	.54	.07	.28	.41	.40	.46	.23	.67	×/ slight.
30.1 "	.11	.43	.28	.20	.15	.09	.15	.55	.06	.31	.47	.42	.48	.29	.64	×/ slight.

4.5 MILLIMETRES (Fig. 12).—This form shows wide diversities from the adult in several respects :—

*Anterior margin.*—The fold is nearly or quite uniform in width from end to end and does not show the regular expansion toward the extremity which is found to characterize adult and half-grown individuals. The flat area of the anterior margin goes entirely around the glabella, and is not interrupted in front of that part of the shield, as it is in the mature trilobite. The narrow part of the flat area where it passes around the front of the glabella is twice as wide as the corresponding part of the marginal fold.

The glabella is remarkable for its narrowness, as compared with the same part of the shield in the adult. The want of volume is not confined to any one part of the glabella, but characterizes it throughout, and is a peculiarity which marks all the immature stages of the Saint John trilobites. This youthful character remains as a permanent feature in var. *malicetus* (described hereafter).

*Glabellar furrows.*—Another point in which the young of *P. eteminicus* differs from the adult is in the position of the glabellar furrows; ordinarily in *P. eteminicus*, a line connecting the two inner points of the fourth furrow is about half way from the front of the dome, but in this young individual it is only a third.

The occipital ring differs widely in form from that of the adult: it is three times as wide in the middle as at the ends, and more than half as wide as long; there is a raised transverse lobe or elevation which occupies more than half of the length of the ring, and on the posterior third a small spine is set; this elevation disappears from the ring in the adult, but its position and former presence is indicated by a forward arching of the occipital furrow in the middle half. This peculiarity of the lobe on the occipital ring which exists in

the young of *P. eteminicus*, but disappears in the adult, is a permanent feature of some adults of *P. acadicus* (see page 103), another species occurring at St. John.

*Posterior margin.*—The furrow and fold are distinct, but exceedingly narrow, and notwithstanding the narrowness of the glabella and occipital ring the posterior margin is shorter in proportion to that portion of the shield (the glabella, etc.) than it is in the adult; the posterior margin was therefore in all respects less completely developed than in the adult. The increase in the width, etc., of the posterior border in *P. eteminicus* is parallel to the change which occurs in *Olenellus asaphoides* Emmons (sp.) as described by S. W. Ford, of Troy, N.Y., in the *Am. Jour. Sci.*, April, 1877. The embryonic forms of that species also exhibit a widening and strengthening of the posterior margin of the shield.

The fixed cheek, on the contrary, at this early stage was of greater comparative size than in the later moults. The anterior end of the ocular lobe in place of being directed toward the summit of the dome of the glabella, as it is later in life, points more towards the anterior margin of the glabella. In very early stages of the organism the fixed cheek was of more importance relatively than other parts which become more prominent at a later period in the life of the trilobite. The relative importance of the cheek and glabella at successive stages is strikingly exemplified in the young of *Conocoryphe Matthewi* of the St. John group, and may also be traced in the embryonic forms of *Olenellus asaphoides*, cited above.

The extreme narrowness of the glabella in this young individual of *P. eteminicus*, as well as its wide occipital ring and large fixed cheek, are paralleled by similar features in var. *malicetus*, described hereafter, which appears to have retained these juvenile features in its later stages of growth.

10.2 MILLIMETRES (Fig. 11). At this stage an advance is made in some points toward the aspect of the adult form.

*Anterior margin.*—The marginal fold is about twice as wide at the ends as in the middle. The flat area still connects in front of the glabella, but is proportionately narrower than in the 4.5 millimetre size, being about equal in width to the marginal folds.

*Glabella.*—There is little change in the position of the furrows, but there is a decided enlargement of the dome.

*Occipital ring.*—The outlines remain, as in the smaller individual, and the spine about one-third from the back of the ring is distinct and directed backward.

*Posterior margin* is somewhat wider and longer in proportion to the occipital ring and the eyelobe than in the 4.5 mm. size. The ocular measurement is six-thirteenths of the three measurements of the facial sutures (See table).

*Sculpture.*—The raised parallel lines on the glabella are very distinct, but only a few could be traced on the anterior marginal fold; the cheeks are distinctly granulated, and a band of tubercles extends from the back of the occipital ring, along the axial line to the dome of the glabella.

21.8 MILLIMETRES (near the size of Fig. 9).—At this stage there is a decided approach to the mature form in several features.

*Anterior margin.*—The fold as in the last, but the flat area in front of the glabella is scarcely one-half of the width of the fold.

*Glabella.*—There is little change except that it is wider at the base. The fourth furrow

is now in its normal position, on a line with the front of the ocular lobe, and about half-way from the front of the dome, as in the full grown trilobite.

*Occipital ring.*—Here there is a decided change in the narrowing of the ring and the straightening of its posterior margin. This part does not hereafter project behind the rest of the shield, as in the earlier stages. The occipital spine recognized in the younger individual has not been detected in this, and the maturer tests of the typical form of *P. etemicus*.

*Posterior margin.*—This is much wider and stronger than before, the gain being chiefly in the width of the the furrow.

*Sculpture.*—The band of minute tubercles, which in the 10.2 mm. size can hardly be discerned with a glass, at this stage becomes quite distinct; and also the extension of it which passes along the posterior furrow. The tubercles on the axial line are also now visible to the unassisted eye. The granulations on the surface of the test are now everywhere distinctly seen, as are also the raised lines on the front of the dome and toward the end of the anterior marginal fold on its inner and outer margins.

26.2 MILLIMETRES, (Fig. 8).—At this stage the cephalic shield exhibits other features of maturity, such as the thickening of the test, strengthening of the posterior margin, &c. Remains of the trilobite of this and the succeeding stage are much more common than those of younger individuals.

*Anterior margin.*—The marginal fold becomes a little wider in front, and at the ends decidedly, but not greatly wider than in the 21.8 mm. size; there is also an increase in the width of the flat area of the anterior margin, so that the whole margin gains in width of sutural measurement at the expense of the ocular lobe.

*Glabella.*—It is in this part of the shield that the most decided change now occurs. There is an increase in all directions, but especially in the dome which expands laterally and increases also in length, so that it begins to push out the front of the anterior margin, with the fold of which it is now in contact.

*Occipital ring.*—This section of the shield is proportionately longer than in the younger stages of growth.

The *posterior margin* does not change much in width, but is much shorter in proportion to the occipital ring.

The *fixed cheek* is proportionately shorter, the arch of the eyelobe fuller than in the earlier stages.

*Sculpture.*—This does not differ materially from that of the form last described.

30.1 MILLIMETRES (Fig. 7).—This is the largest, well-preserved head which has been obtained, and shows a continued enlargement of the glabella. It presents some differences from the younger stages which may be varietal or due to pressure and distortion.

The *anterior margin* is proportionately somewhat smaller than in the 26.2 mm. size.

*Glabella.*—The dome is larger, both longitudinally and transversely, and the fourth furrow is more than half-way from the front of the dome.

The *posterior margin* is somewhat longer and considerably wider than in the last, and the *fixed cheek* has gained in length and width.

The *sculpture* is the same as that given in the description on a previous page of the species *P. etemicus*.

I have described thus fully the gradual change in the cephalic shield of *P. eteminicus* during its growth, because of the interest that attaches to any feature of structure bearing on the origin and development of species, especially of such remote antiquity.

In the changing form of the glabella and other parts of the buckler, there are features which remind one of the changes observed by Barrande, in the growth and development of *Sao hirsuta*, a trilobite of Bohemia. To the earliest stages of that species the Acadian beds have as yet furnished no parallel. But of that wherein the central lobe of the cephalic shield begins to be segmented, there is an indication in the earliest known form of *P. eteminicus* in the preponderance of the occipital ring, which projects behind the posterior margin, has a thin and leaf-like aspect behind, and possesses much greater comparative width than at the later stages of growth. The weakness of the posterior margin, also, in the early stages of our species, indicates its immaturity and recent appearance.

The gradual development of the anterior end of the glabella in *Sao*, finds its counterpart in *P. eteminicus* in the retreat of the furrows from the front of the glabella during growth, and the gradual absorption of the flat area of the anterior margin. But in the enlargement of the front, or dome in *P. eteminicus*, a characteristic feature of the genus *Paradoxides* becomes prominent, which is not to be looked for in *Sao*, and which does not appear in the figures of *S. hirsuta*.

It is not impossible that there may also be some meaning in the gradual retreat of the eyelobe from the posterior margin by the widening of this part, and by the less rapid growth of this lobe than of other parts as the animal continued to increase in size. This, it appears to the writer, may be taken to indicate that the forms with continuous eye-lobes are a more primitive type than the *Paradoxides* with contracted eyes. Looked at from this point of view the var. *quacoensis* (described hereafter) is the most advanced type of the genus yet found in the St. John basin.

#### VARIETIES OR SUB-SPECIES OF *P. ETEMINICUS*.

The form of trilobite described in the preceding pages is the central one of a number showing various points of diversity, but possessing in common one distinguishing character which separates them from the two succeeding species, viz: fine concentric raised lines on the front of the glabella. These points of diversity are in some cases probably of specific value but, for the present and till fuller knowledge is obtained, it seems desirable to keep together under one specific head the various forms having the raised lines on the glabella. The forms thus characterized, omitting the central type already described, may be dealt with in succession, beginning with those that have the shortest axial diameter.

##### Var. *SURICOIDES* (Figs 4-6).

This variety is not so common as *P. eteminicus*, but appears to have attained a larger size. It differs from that form in the following respects:—

*Glabella*.—The length and breadth are nearly equal. The dome of the glabella is larger, higher and oblately orbicular. The glabellar furrows are more heavily impressed: the fourth furrow is three-fifths (the length of the dome) from the front of the dome.

The occipital ring is rounded along the posterior margin in a more regular curve than

that of *P. eteminicus*; it is also more strongly arched along the middle; is lenticular rather than rectangular in outline, and the spine is more prominent.

*Sculpture*.—The general surface of the shield is smooth, even when viewed with a lens of one inch focus. But there are two bands of small tubercles, as in *P. eteminicus*, which seem more distinct in the variety, owing to the smoothness of the shield elsewhere.

I append measurements of a few heads to show the peculiarity of form, etc. The table is in all respects the counterpart of that on a previous page showing the stages of growth of *P. eteminicus*.

MEASUREMENT OF CEPHALIC SHIELDS.

Stages of Growth.	Suture.				Axial Line.					Transverse Diameters.						Distortion.
	Posterior Margin.	Cord of Eye-lobe.	Anterior Margin.	Sine of Eye-lobe.	Occipital Ring	Glabella.			Anterior Margin.	Basal.		Middle.		Anterior.		
						First Lobe.	Second Lobe.	Dome.		Posterior Margin.	Occipital Ring	Fixed Cheek.	Glabellar.	Anterior Margin.	Glabell.	
6.4 millimetres.	.07	.40	.25	.15	.15	.05	.10	.45	.15	.30	.40	.45	.45	.35	.65	\
13.5 "	.07	.43	.29	.19	.14	.10	.12	.52	.10	.29	.45	.43	.52	.29	.65	+
19.9 "	.08	.44	.26	.19	.16	.08	.10	.55	.10	.35	.45	.45	.50	.32	.70	± slight.
35.3 "	.09	.39	.22	.19	.15	.08	.10	.55	.06	.29	.40	.40	.46	.23	.69	\
37.1 "	.10	.38	.24	.16	.16	.09	.11	.59	.06	.30	.47	.38	.53	.23	.74	†

#### Growth and Development of the Young.

Although this variety has not been found of so small a size as *P. eteminicus*, those observed show a similar development of the test during growth.

6.4 MILLIMETRES (Fig. 6).—At this stage there are marked differences from the adult form.

*Anterior margin*.—The marginal fold is slightly wider at the ends than in the middle, and the flat area goes around the front of the glabella, where it is as wide as the marginal fold.

*Glabella*.—The dome is more prominent than in *P. eteminicus* of similar age; and the fourth furrow is behind the line of the eyelobe, and already nearly half way from the front of the dome.

The *occipital ring* is very wide in the middle, with an elevated central half, as in the young of *P. eteminicus*, but the spine is set further back on the ring. The *posterior margin* is narrow and weak when compared with the adult form.

*Fixed cheek*.—The cord of the eye-lobe is four-sevenths of the sum of the measurements of the facial suture.

*Sculpture*.—Parallel raised lines are distinctly seen on the anterior marginal fold and on the dome of the glabella.

13.5 MILLIMETRES.—In this there are decided changes from the earlier moult, all in the direction of the adult form.



*Anterior margin.*—The marginal fold is a half wider at the ends than in front of the glabella. The flat area still connects in front of the glabella, but has been reduced in width to one half of the breadth of the corresponding part of the marginal fold.

*Glabella.*—There is a marked increase in the size of the dome, and the fourth furrow is at its normal position in the adult, viz., on a line with the front of the ocular lobe. The fourth furrow is now also more than half way from the front of the dome.

*Occipital Ring.*—The elevated lobe has disappeared from the middle of the ring, and in place of the width being more than a third of the length it is now less.

*Sculpture.*—So far as it is preserved does not differ from the 6.4 mm. size.

19.9 MILLIMETRES (Fig. 5).—At this stage of growth the furrows become heavier and the front of the glabella somewhat conical.

*Anterior margin.*—The limbs of the flat area are now separated and the marginal fold meets the front of the glabella.

*Glabella.*—The dome is larger proportionately in both diameters than in the last described stage, but the position of the fourth furrow remains unchanged. The *occipital ring* becomes more tumid and increases in length.

The *posterior margin* also gains in width and length.

The *sculpture* is that of the mature form.

35.3 MILLIMETRES—The gap between this size and the last gives room for considerable change of form.

*Anterior margin.*—The fold is now more than twice as wide as the extremity as in front of the glabella. The glabella gains a little in volume, and the fourth furrow is now three-fifths from the front of the dome. The posterior margin continues to gain in width. The fixed cheek is narrow and the ocular lobe shorter.

37.1 MILLIMETRES (Fig. 4).—In this, the largest individual of this variety obtained, which was sufficiently well preserved for comparison, but little change from the last form is observable, if the effects of pressure be allowed for. The continued diminution of the ocular lobe is however, a decided feature, and there is also a slight enlargement of the dome.

It will be observed that the development of this variety does not proceed *pari passu* with that of *P. eteminius*.

*Locality.*—Portland, near St. John, in Division 1 c. Has not been collected elsewhere.

*Name.*—In allusion to the Souriquois tribe of Acadian aborigines.

#### Var. BREVIATUS.

This form is a common one, and like the last differs from the type in its shorter glabella, and in having a wider and more elevated dome. The length of the buckler is about equal to the transverse measurement of the fixed cheek and the glabella at the first furrow.

*Anterior margin.*—The extremities of the marginal fold are proportionately narrower and more convex than in the two preceding forms.

*Glabella.*—The length from the first furrow is equal to the width, and this furrow is heavily impressed all across. The fourth furrow is more than three-fifths from the front of the dome.

**Sculpture.**—This differs from the last and from *P. eteminicus* in several respects. The band of tubercles on the axial line is not conspicuous, because the whole surface of the glabella is more or less granulated, and these granulations merge gradually into the raised lines that decorate the front of the glabella. In this variety, too, the raised lines, while they are heavier along the front of the glabella than in the two last, do not show conspicuously toward the top of the dome, and often are quite absent from the upper half. Another point of difference from var. *suricoides* is the distinct granulations of the whole of the fixed cheek, etc., and these granulations differ from those of *P. eteminicus* in being coarser and thus resemble the markings on the surface of *P. acadicus* of the St. John beds.

The following are measurements of the heads of this variety:—

MEASUREMENTS OF THE CEPHALIC SHIELD.

Stages of Growth.	Suture.				Axial Line.				Transverse Diameter.						Distortion.
	Posterior Margin.	Cord of Eye-lobe.	Anterior Margin.	Sine of Eye-lobe.	Occipital Ring.	Glabella.			Posterior Margin.	Occipital Ring.	Fixed Cheek.	Glabell.	Anterior Margin.	Glabell.	
						First Lobe.	Second Lobe.	Dome.							
10.9 millimetres.	.06	.53	.24	.21	.08	.12	.53	.08	.32	.50	.47	.53	.85	$\frac{1}{2}$ slight.	
15.4 "	?.08	?.46	.29	?.21	.14	.03	.13	.58 (.62)	.06	?.46	?.46	?.46	.58	?.37	.75 (.83)
21.8 "	.12	.50	.22	.21	.15	.10	.12	.56	.06	.32	.56	.51	.51	.30	.75 × ↑ ?
23.7 "	.12	.49	?.27	?.23	.18	.09	.16	.51	.05	.34	.53	.47	.60	.27	.78 / slight.

**10.9 MILLIMETRES.**—*Glabella.*—At this period the glabella is already quite wide, a characteristic feature of this form, and the dome well developed. The fourth furrow is as yet less than half way from the front of the dome.

*Occipital Ring.*—This exhibits the usual predominance over other parts of the shield in the early stages of the growth. The width is considerably more than one-third of the length. The occipital spine has not been observed at any stage in the growth of this variety.

The *posterior margin* is narrower and weaker than at the corresponding stages of any of the preceding forms.

The *fixed cheek* is well developed and the ocular lobe proportionately longer than at later stages of growth.

*Sculpture.*—The bands of tubercles, the raised lines on the glabella, and the granulation of the general surface of the test can already be very easily recognized with a moderate power.

**15.4 MILLIMETRES (Fig. 3).**—*Glabella.*—Allowing for the absence of flattening, this part is larger than in the preceding stage, and the fourth furrow is about three-fifths from the front of the dome.

The sculpture is very distinct and characteristic of this variety.

**21.8 MILLIMETRES (Fig. 1).**—The *anterior margin* at this age shows no space between the glabella and the fold.

*Glabella*.—The fourth furrow is at this stage somewhat less than three-fifths from the front of the dome.

The *occipital ring* is proportionately much narrower than in 10.9 mm. stage of this variety, the width being less than one-third of the length.

The *posterior margin* at this stage is about twice as wide proportionately as in the preceding.

The length of the *ocular lobe* on the contrary, is reduced.

*Sculpture*.—At this stage the concentric raised lines disappear from the higher part of the dome, but are still distinct for about half of the distance up its slope. In other respects the sculpture corresponds with that of the earlier stages.

23.7 MILLIMETRES. — *Glabella*.—The fourth furrow is somewhat more than three-fifths ( $\frac{11}{10}$ ) from the front of the dome.

*Occipital ring*.—The width is scarcely more than a quarter of the length.

*Fixed cheek*.—The ocular lobe is somewhat smaller than in the last described stage.

The development of the glabella in this form appears to take place more rapidly than in either of the preceding (*eteminicus* and *suricoides*). Even the smallest has a fully rounded and raised dome, and at so early a stage as 15.4 mm.; the fourth furrow is found to be about three-fifths from the front of the dome.

*Locality*.—Found at Portland, N.B., in Division 1 c. with the two preceding forms.

#### Var. MALICITUS (Fig. 13).

This form presents some marked differences from *P. eteminicus*.

The *occipital ring* is very wide, being nearly half as wide as it is long. It is about one-fifth of the length of the cephalic shield.

*Fixed cheek*, is very wide and strongly arched upward at the outer side, a shallow depression crosses it lengthwise, and it is strongly deflected downward in front and behind. This is the only well-grown individual found in the St. John Cambrian rocks in which the width of the fixed cheek exceeds that of the glabella. The eyelobe is very long and prominently elevated at the posterior end; it is a fifth longer than that of *P. eteminicus*—of a corresponding size.

*Sculpture*.—The surface is not sufficiently well preserved to show the markings, except a part of the concentric raised lines around the front of the glabella, and these appear to be similar to those of the three forms already described.

The anterior margin is deficient in this specimen, but supposing it to resemble that of *P. eteminicus*, the following measurement will represent the cephalic shield:—

Length.	Suture Measurement.				Axial Diameter.					Transverse Diameter.						Distortion.	
	Posterior Margin.	Cord of Eye-lobe.	Anterior Margin.	Side of Eye-lobe.	Occipital Ring.	Glabella.			Anterior Margin.	Basal.		Middle.		Anterior.			
						First Lobe.	Second Lobe.	Dome.		Occipital Ring.	Posterior Margin.	Occipital Ring.	Fixed Cheek.	Glabella.	Anterior Margin.		Glabella.
21.8 millimetres	.12	.54	.24	.24	.18	.09	.15	.53	.06	.37	.43	.50	.47	.32	.05	0	

*Locality*.—Portland, N.B. In Division 1 c.

*Name.*—In reference to the Malicites, a tribe of Acadian aborigines.

Var. QUACOENSIS (Fig. 14 and 14a).

This differs from *P. eteminicus* in several respects.

*Anterior margin.*—The fold is only one-half wider at the extremity than in front of the glabella.

The glabella is broader than that of *P. eteminicus*, and the fourth furrow is three-fifths from the front of the dome.

*Fixed cheek.*—The ocular lobe is proportionately shorter than in any of the preceding forms.

*Sculpture.*—The anterior margin has finer and more waving raised lines, which at the end of the fold are about 15 in number. The raised lines on the glabella are more irregular in their course and are not so prominent as in the preceding forms; there are about  $5\frac{1}{2}$  or 6 raised lines in the space of a millimetre, and they do not extend to the base of the dome, for around the base, for a width of from 2 to  $3\frac{1}{2}$  millimetres, these raised lines are absent. The largest tubercles on the test are along the posterior margin of the occipital ring; the space immediately around the occipital spine has very small tubercles, whereas in *P. eteminicus* the largest tubercles are on the corresponding space. The cheek is granulated and the central part is crossed by a number of low, flat, reticulating ridges that radiate from the glabella toward the occipital lobe.

#### MEASUREMENT OF CEPHALIC SHIELDS.

Length.	Suture.				Axial Diameter.					Transverse Diameters.						Distortion.
	Posterior Margin.	Cord of Eye-lobe.	Anterior Margin.	Sine of Eye-lobe.	Occipital Ring.	Glabella.			Anterior Margin.	Basal.		Middle.		Anterior		
						First Lobe.	Second Lobe.	Dome.		Posterior Margin.	Occipital Ring.	Fixed Chord.	Glabell.	Anterior Margin.	Glabell.	
34 millimetres.	·15	·38	·20	·10	·14	·10	·15	·57	·06	·31	·41	32	·41	·23	·62	o

*Locality.*—Hanford Brook, near Quaco, in St. Martin's Parish. Probably from Division 1 c.

Var. PONTIFICALIS (Figs. 15 and 15a).

This differs from all the preceding, and may be distinguished by the following peculiarities:—

*Anterior margin.*—The flat area is nearly three times as long as it is wide; there is a thin sharp ridge, perhaps accidental, dividing off the front third from the rest.

The glabella at the first furrow is proportionately much broader than the others, and the side arches of the second furrow almost meet. The fourth furrow is three-fifths from the front of the dome.

*Sculpture.*—The raised lines on the front of the glabella are very distinct, and there are from 8 to 4 in the space of one millimetre. These on the anterior marginal fold are finer, and there are at least 15 of them toward the end of the fold. With the aid of a lens

of one inch focus, the rest of the surface of the test, which appears smooth to the eye, is seen to be covered with very minute granulations.

The following measurement will give a more complete idea of the form of this head :

Length.	Suture.				Axial Diameter.					Transverse Diameters.						Distortion.
	Posterior Margin.	Cord of Eye-lobe.	Anterior Margin.	Sine of Eye-lobe.	Occipital Ring.	Glabella.			Anterior Margin.	Basal.		Middlo.		Anterior.		
						First Lobe.	Second Lobe.	Dome.		Posterior Margin.	Occipital Ring.	Fixed Cheek.	Glabella.	Anterior Margin.	Glabella.	
41 millimetres.	·11	·45	·22	·17	·12	·09	·12	·62	·03	·22	·27	·36	·50	·22	·69	x / x

*Locality*—Found at Portland in Division 1 c.

The numerous raised lines on the anterior margin of this variety, as well as the sharp sinus in the anterior part of the suture, seem to associate this head with a moveable cheek similarly characterized, and the pygidium found with this form differs from the ovate pygidium of common occurrence, which is to be associated with *P. eteminicus*. It is probable that when better known *pontificalis* will be found to be a distinct species.

As a further aid to the discrimination of these closely allied forms, and to show their distinctness, the following table, based on the relative proportions of the adult forms, will be of service:—

Name.	Form of anterior sinus of Facial Suture.	Fourth furrow from front of Dome.	Cords of Suture.			Middle Transverse Diameter.	
			Proportion of the			Proportion of the	
			Posterior Margin.	to Eye-lobe & {	Anterior Margin.	Fixed Cheek.	Glabella at first furrow.
var. brevatus.	short and open.	more than $\frac{1}{2}$	1	4·35	2·65	1	1·58
" suricoides.	broad and deep.		1	4·35	2·60	1	1·57
sp. eteminicus.	broad and open.	$\frac{1}{2}$	1	4·25	2·50	1	1·43
var. malicitus.	?	?	1	4·65	?	1	0·94
" quacoensis.	broad and open.	$\frac{1}{2}$	1	2·40	1·40	1	1·53
" pontificalis.	sharp and deep.	$\frac{1}{2}$	1	3·85	1·85	1	1·80

#### PARADOXIDES ACADICUS. (Figs. 16-18).

The anterior margin is regularly rounded and strongly arched backward. The marginal fold is moderately convex and about twice as wide at the extremity as in front of the glabella. The flat area is very small, and at the suture about as wide as the marginal fold.

The glabella is about an eighth longer than wide; it expands regularly from the base



to a point somewhat in advance of the fourth furrow, whence it is regularly rounded to the front.

The glabellar furrows are all heavily cut. The first two cross the axis of the glabella; of these the first is arched decidedly backward, and is somewhat more heavily impressed in the outer, than in the middle third. The second furrow strongly indents the glabella parallel to the transverse axis; it is more lightly impressed in the middle quarter than elsewhere. The two anterior furrows are in pairs. The third fails to cross the glabella by less than a third of the glabella's width; it begins within the margin of the glabella and is directed forward at an angle of about fifteen degrees. The fourth furrow begins on the edge of the glabella, and scarcely extends one quarter of the way across it.

The occipital ring is more than twice as long as wide; it is regularly convex and moderately arched vertically; a little behind the middle of the ring is a short tuberculous spine. In some of the largest heads the middle half of the ring is raised into a broad, rather flat lobe which bears the spine. The occipital furrow is more strongly impressed in the outer quarter than in the middle.

The posterior margin is moderately arched backward; the fold is regularly convex and moderately arched vertically. The furrow is scarcely as wide as the fold, and is rounded in the bottom.

The fixed cheek is subtrapezoidal in form, is convex and has an elevation at the posterior inner angle; it is strongly depressed in front, and the bounding furrows are distinct. The ocular lobe makes an open parabolic curve, and is prominently raised all round, but especially at the extremities. The curve of the posterior third of the ocular lobe in this species is more open than in that of the preceding species or its varieties.

*Sculpture*.—Parallel raised lines appear only on the front half of the marginal fold, where there are about five. Elsewhere the surface of the test is covered with closely set granulations visible to the naked eye.

This neat little species is easily distinguished from all the preceding by its granulated surface, and by the absence of raised lines on the front of the glabella.

Locality, Portland, N.B., in Division 1 c, and young at Hanford Brook, St. Martin's.

#### *Growth and Development of the Young.*

Owing to the want of a well preserved test, exhibiting the early stages of this species, its growth and development cannot be so well shown as that of *P. etemicus* and its allies. Nevertheless, there is sufficient to show similar changes of form, as may be gathered from the following table :—

## MEASUREMENT OF CEPHALIC SHIELD.

Length.	Suture.				Axial Diameter.					Transverse Diameters.						Distortion.
	Posterior Margin.	Cord of Eye-lobe.	Anterior Margin.	Sine of Eye-lobe.	Occipital Ring.	Glabella.			Anterior Margin.	Basal.	Middle.	Anterior.				
						First Lobe.	Second Lobe.	Dome.								
7.7 millimetree.	.08		.27		.17	.08	.10	.42	.15		.33		.42	.27	.58	— slight.
8.3 "	.09	.58		.17	.16	.08	.11	.54		.31	.39	.37	.39		.65	+
10.9 "	.09	.53	.21	.18	.16	.09	.12	.53	.09	.30	.47		.50		.71	↓
12.8 "	.09	.50	.20	.22		.10	.10	.55	.07	.35	.45	.40	.45	.20	.62	+
12.8 "	.09	.45	.25	.22	.15	.10	.13	.52	.07	.37	.45	.42	.48	.25	.60	—
15.4 "	.08	.46	.23	.21	.14	.08	.14	.56	.06	.33	.42	.44	.50	.25	.66	—

*Marginal Fold.*—In the first stage observed (fig 18), there was a space in front of the glabella separating that part of the shield from the marginal fold; at this period the space in front of the glabella was equal in width to the marginal fold, but at the 10.9 mm. it is obliterated by the meeting of fold and glabella.

*Glabella.*—The glabella dome shows the usual lateral enlargement, and the fourth furrow the gradual retrocession from the front of the dome; in the youngest stage observed it is half-way from the front, then in later stages the fourth furrow is found to be about three-fifths from the front as in *P. eteminius*, and finally at the largest stage (fig. 17) it is three quarters from the front of the dome.

The *occipital ring* as in *P. eteminius* and its allies becomes gradually reduced in width, and the posterior side of the shield lengthened as in those forms.

The *fixed cheek* changes its form during growth, increasing in width and decreasing in length. The increase of the width of the fixed cheek is more decided and regular in this species than in *P. eteminius* and its related forms, and in this respect reminds one more forcibly of the gradual outward arching during growth of the eye-lobe in *Olenellus asaphoides*. The gradual modification of the shield of *P. acadicus* is evidently parallel to that which occurs under similar conditions in *P. eteminius* and its allies.

*Sculpture.*—The youngest shield of *P. acadicus* was obtained at Hanford Brook in St. Martin's, and like most of the tests from that locality is very thin: the cheeks are wrinkled by pressure, and the granulations on the surface are very delicate; a lens of 1 in. focus is sufficiently powerful to resolve the markings. The head is remarkable for the unusually great expansion of the anterior margin, and there are one or two raised lines discernible on the front of the fold. At the 12.8 mm. stage (fig. 16) the granulations on the test of this species become visible to the naked eye, and in the mature trilobite are very distinct.

## PARADOXIDES LAMELLATUS (Hartt).

Professor C. F. Hartt describes this "as a small species distinguished from several others found with it by the presence of a number of sharp perpendicular laminae on the

anterior lobe of the glabella." The writer has met with a form which appears to be a variety of the species with vertical interrupted plates on the front of the glabella.

Var. *LORICATUS* (Fig. 19)

The anterior margin is arched moderately around the front of the glabella. The marginal fold is almost twice as wide at the extremity as in front of the glabella. The flat area is small and short.

The glabella is broad and elevated in front. The anterior slope of the dome is ornamented with about four rows of elevated ridges or plates, of unequal length laterally; those of the three outer rows are generally longer than those of the inner row, some of which are so short as to resemble tubercles rather than plates; the length of the plates in the outer row is about equal to the width of the flat area of the anterior margin. Within the rows of plates the dome of the glabella is decorated with rows of tubercles parallel to the rows of plates. The elevated ridges are hollow, and consist of an upward folding of the substance of the test, there being a cavity on the inside of the test corresponding to the ridge on the outside.

*Sculpture*.—The anterior marginal fold has a few raised, longitudinal lines near the extremity, and the whole surface of the test is covered with minute granulations which are just discernible with a lens of 1 in. focus.

*Locality*, Portland, N. B. In Division 1 c.

*Size*.—The fronts of two cephalic shield were found: of these the larger indicated a buckler about half an inch long.

*Conclusions.*

Though it has not been possible to exhibit a complete series showing the stages of growth of any of the trilobites of the St. John group, a sufficiency has been obtained to show that the growth and development of the young of different species led upward from embryonic forms similar in certain general features to those of *Sao hirsuta* and *Olenellus* (*Elliptocephalus*) *asaphoides*. These features of advancement toward maturity in the St. John *Paradoxides* may be briefly expressed as follows:—

1. Widening of the extremities of the anterior marginal fold, and absorption of the central part of the flat area.
2. Enlargement of glabella in all directions and retreat of the fourth furrow from the front of the glabella.
3. Transverse lengthening and axial condensation of the occipital ring.
4. Enlargement and strengthening of the posterior margin.
5. Longitudinal contraction of the eyelobe.

Of these modifications of the cephalic shield perhaps the changes in the glabella were of the greatest moment. The way in which the enlargement of this portion of the shield took place at the different moults is perhaps indicated by the peculiarities of two of the forms.

In variety or sub-species, *quacoensis*, there is a band around the base of the dome of the glabella from which the raised concentric lines are entirely absent, and the smoothness of the surface is affected only by minute granulations. This smooth band, it may be supposed, is a late addition to the glabella; it is considerably wider ( $3\frac{1}{4}$  mm.) at the insertion of the

eyelobe than in front of the glabella (2 mm.) so that, if the addition to the glabella was made in the way supposed, while the vertical height of the glabella was increased in all parts, the greatest gain would have been in the middle.

In *P. lamellatus*, Hartt, var. *loricatus*, the vertical plates occur at regular intervals along the slope of the dome of the glabella as though they marked regular stages of growth: and the raised lines on the slope of the dome of *P. etemicus* and its allies may indicate the transfer of narrow zones of the head shield to the glabellar area, and those on the anterior marginal fold, of similar belts to the rim of the shield; for the lines on the latter are not parallel to the inner but rather to the outer margin; on that side, also, the lines are more crowded, as though the fold were growing wider and more compact at the expense of the flat area. Whether there was any such process of condensation of the test between the periods of moulting or not, it is clear that there was a gradual change in the proportions of different parts of the shield during the advance from youth to maturity.

It is remarkable that the occipital spine in many of the Saint John forms of the Paradoxides should become reduced, and in some cases should disappear altogether in the later stages of growth. It is present in the younger stages of all the species and varieties, and its gradual reduction in size accompanies the condensation of the occipital ring. Originally it appears to have been of more importance, and perhaps with the ring served as a protection to the posterior immature extension of the body of the trilobite. Spence Bates, who has studied the early stages of the common shore crab (*Carinus menas*), observed the appearance of a prominent dorsal spine in the second zoëa stage of that crustacean. The great prominence of this process at so early a stage of *Carinus* reminds one of the importance of the occipital ring and spine in the early stages of the St. John Paradoxides.

Another feature of growth which the examination of the tests of these Cambrian trilobites has revealed is the rapid changes which occurred during the earlier stages of growth. Development did not always proceed at a regulated pace. For instance, the surface of the dome of the glabella of *P. lamellatus*, Hartt, within the rows of plates, presents quite a different appearance as regards the surface markings, to that which later marks the plated slopes of the dome. So also in the tests of *P. acadicus*, the 10.9 mm. size, has many embryonic features that are wanting in the next size: and the arrest in the backward movement of the fourth furrow of the glabella of the 15.4 mm. size (if not earlier) in the variety *breviatus* (of *P. etemicus*) is also significant of an early maturity in that form, with which other features of this test agree. In the more complete series of *P. etemicus*, it is plain that the most rapid and vital changes occurred in this species, in the earliest stages of growth, and that the development in the later ones was slower, and was arrested in one point after another as the trilobite approached maturity. Rapid change of form and the earlier stages of growth and development on the lines indicated above, characterized the Saint John Paradoxides; just as is in *Sao hirsuta* and *Olenellus asaphoides* corresponding changes in the process of growth fixed the distinguishing features of those two species.

## EXPLANATION OF PLATE.

Fig. 1.—*Paradoxides clemencius*, var. *breviatus*, flattened.

- |        |   |   |   |                     |   |
|--------|---|---|---|---------------------|---|
| " 2.   | " | " | " | "                   | shortened by pressure.  |
| " 3.   | " | " | " | "                   | young.  |
| " 4.   | " | " | " | <i>auricoides</i> , | flattened.  |
| " 5.   | " | " | " | "                   | half-grown and flattened.   |
| " 6.   | " | " | " | "                   | fry, flattened, magnified 2 diam.   |
| " 7.   | " | " | " | "                   | type, flattened by pressure.  |
| " 8.   | " | " | " | "                   | younger test, flattened.  |
| " 9.   | " | " | " | "                   | laterally contracted.   |
| " 10.  | " | " | " | "                   | young, thin test.   |
| " 11.  | " | " | " | "                   | magnified 2 diam.   |
| " 12.  | " | " | " | "                   | fry, " 4 "  |
| " 13.  | " | " | " | "                   | var. <i>malicetus</i> .   |
| " 13a. | " | " | " | "                   | outline in profile.   |
| " 14.  | " | " | " | "                   | <i>quacoensis</i> , adult.  |
| " 14a. | " | " | " | "                   | outline in profile.   |
| " 15.  | " | " | " | "                   | <i>pontificalis</i> , flattened, (the right side is sketched in to correspond to left). |
| " 15a. | " | " | " | "                   | right anterior margin of another test.  |
| " 16.  | " | " | " | "                   | <i>acadiens</i> , with anterior margin arched.  |
| " 17.  | " | " | " | "                   | flattened, " spread.  |
| " 18.  | " | " | " | "                   | young, flattened, magnif. 2 diam.   |
| " 19.  | " | " | " | "                   | <i>lamellatus</i> , Hart, var. <i>loricatus</i> .                                       |
| " 20.  | " | " | " | "                   | sp., large species, immature.   |
| " 21.  | " | " | " | "                   | sp., " left third of cephalic shield.   |



